



Manufacturing of PIP-II high power couplers - Experience feedback

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A Partnership of:

US/DOE

India/DAE

Italy/INFN

UK/UKRI-STFC

France/CEA, CNRS/IN2P3

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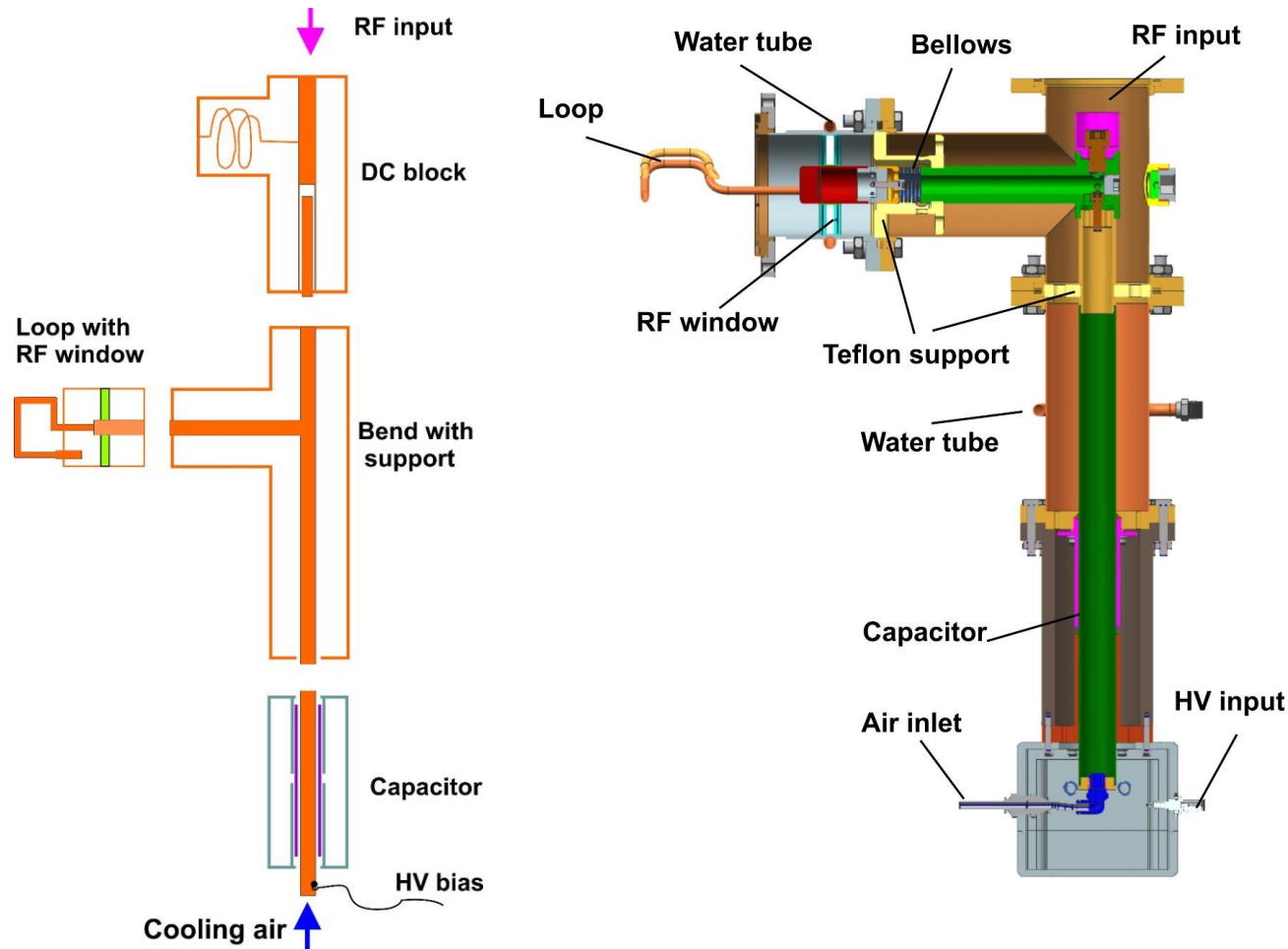
Several prototypes of PIP-II couplers were produced:

RFQ couplers, 162.5 MHz: – two couplers + 4 windows + 2 windows + 10 ceramics.

SSR1 couplers, 325 MHz: ~ 10 couplers and ~ 20 RF windows with antennas.

650MHz couplers: 2 air parts, 2+2 vacuum parts, 4 RF windows with antennas.

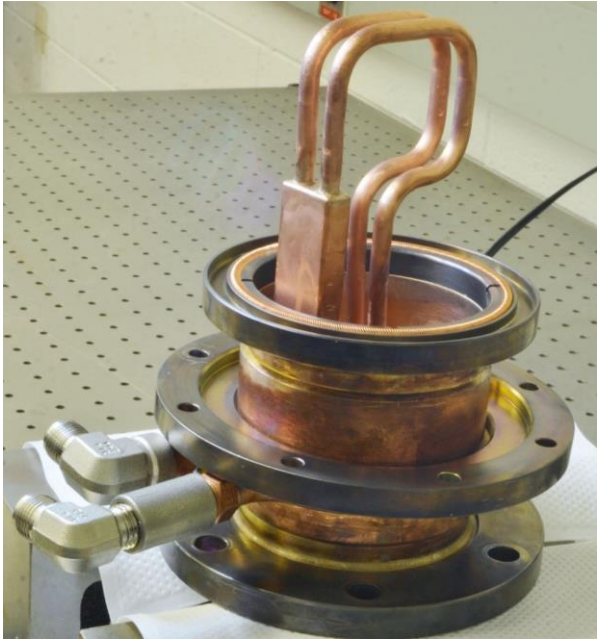
RFQ, first design.



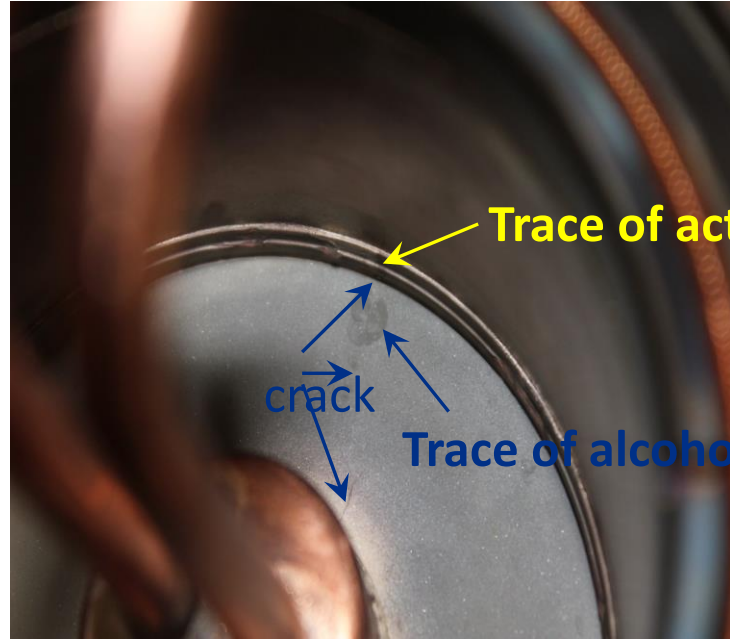
RF window: 3-inch ceramics. Air cooling of inner conductor and water cooling if outer conductor.

Two couplers and 4 RF windows produced by "Mega Inc." Mega is very good company for producing air filling waveguide systems. But Mega had no previous experience to braze RF windows. Finally they produced 4 windows with antenna with big delay. One window had a small leak but was accepted and installed to RFQ because of big delay.

70 kW, CW, 162.5 MHz coupler.



Ceramics window unit.



Broken ceramics.

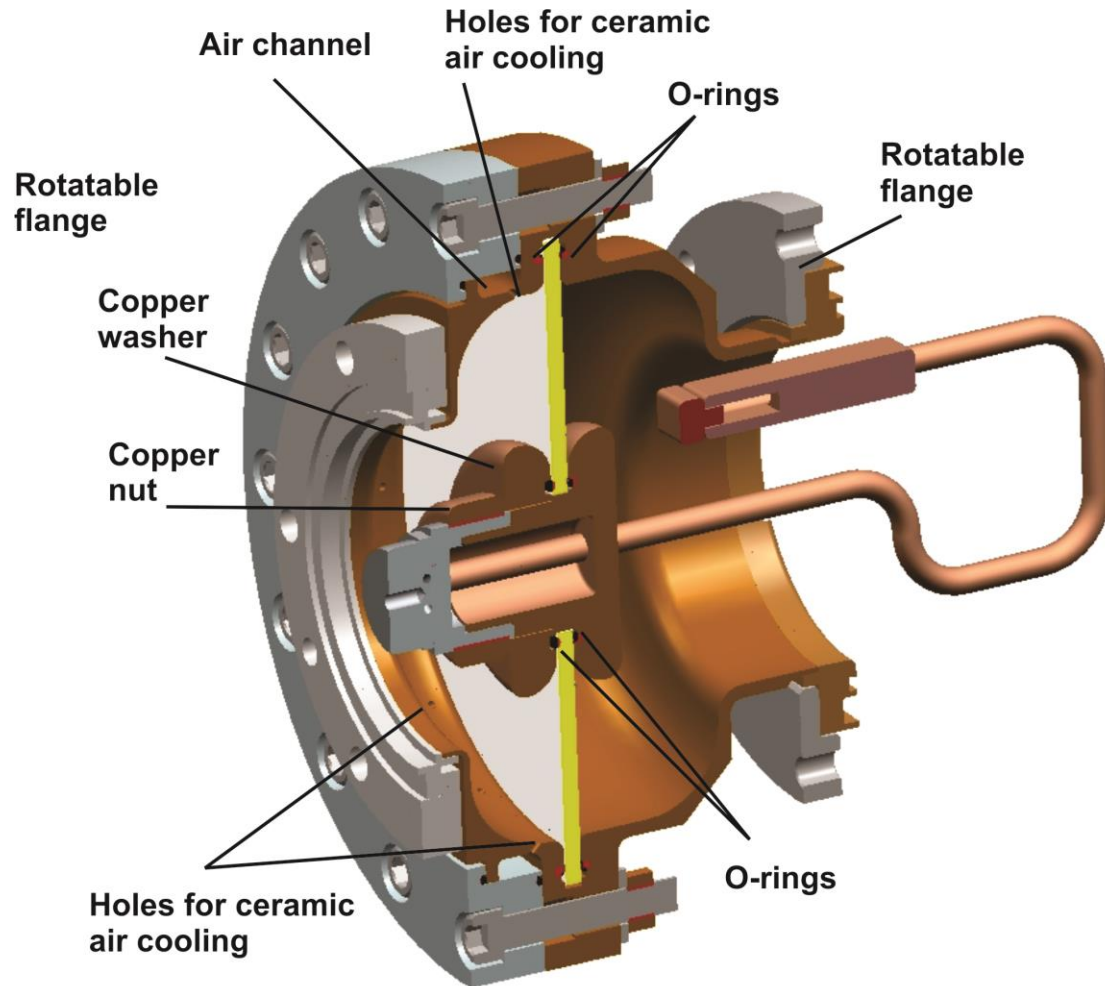
Finally, we decided to design new window with replaceable ceramics.

After some operation at 65 kW, CW two window were broken. Reasons are not clear enough. Probably the quality of fabrication was not good enough. Another possible reason is overstressed window at the beginning of operation: by mistake air rate was 3 time less then necessary.

Ceramics was coted with TiN, 20nm. Coating was made by subcontractor of “Mega”. We could not check quality of coating and thickness.

During operation, before brake, ceramics become conductive, it was impossible to apply bias. Conductivity disappeared after window opening to air. Ceramic change color: initial color was light yellow, after operation – gray. Was this transformation of TiN?

Windows with replaceable ceramic and Viton O-rings were designed.



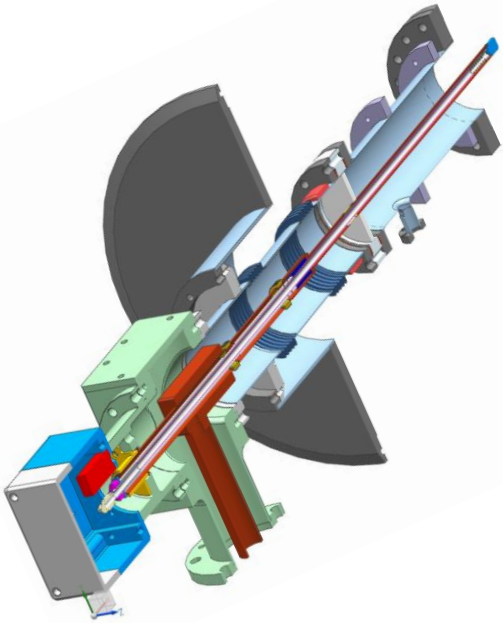
Size of ceramics: 6" x 4mm.

Ceramic disk is not coated. Multipactor is suppressed by high voltage bias, ~ 4 kV.

Two window units work well without signs of degradation at power levels ~ 60 kW, CW.

SSR1, 325 MHz coupler.

First 3 windows with antenna was produced by “Omley” company. The company specializes in the production of vacuum ceramic products. Despite this the quality of brazing was rather poor: windows were vacuum tight but brazing materials can be pilled off. Nevertheless two couplers were tested successfully up to 30 kW, CW, full reflection. Third window was successfully tested with SSR1 cavity.



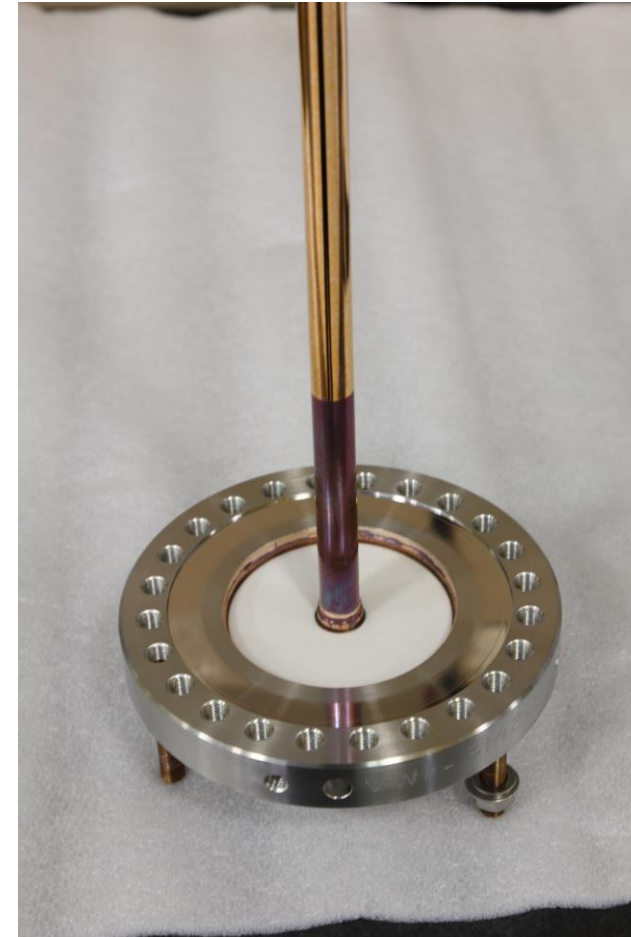
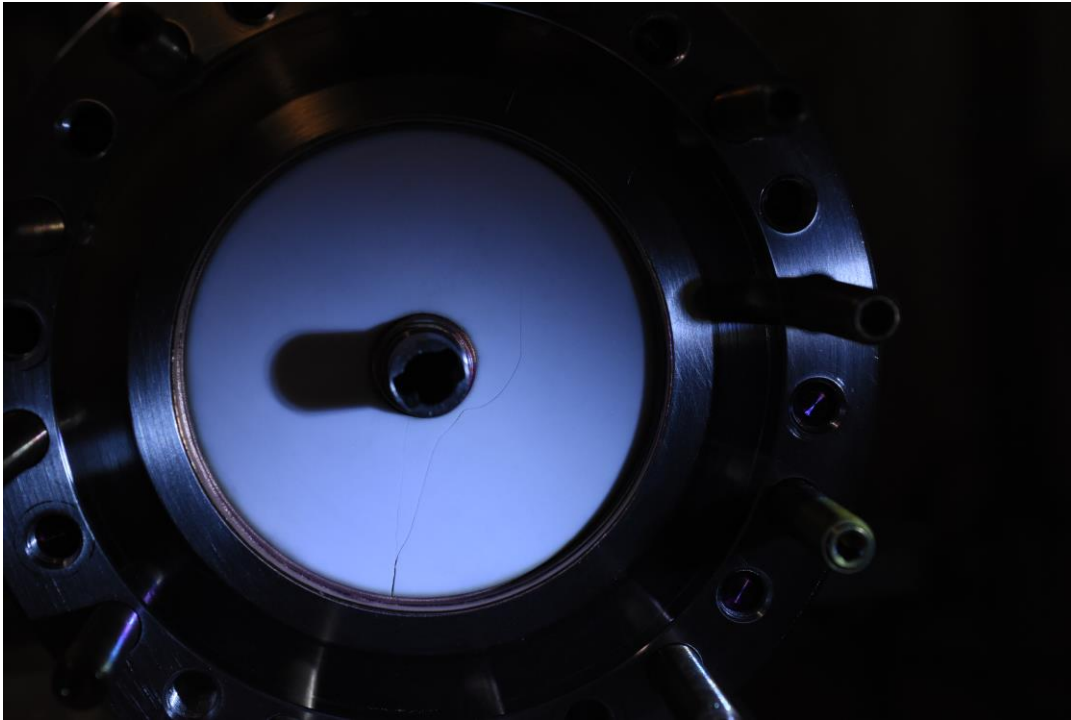
We change company for production next 10 couplers. Mega won the bidding but failed to produce the couplers. Finally all couplers, which now are using in first SSR1 cryomodule were produced by CPI.

Three of first CPI coupler were produced with not so good ceramic to save time (We were late ~ 2 years). One of window was broken at 20 kW full reflection.

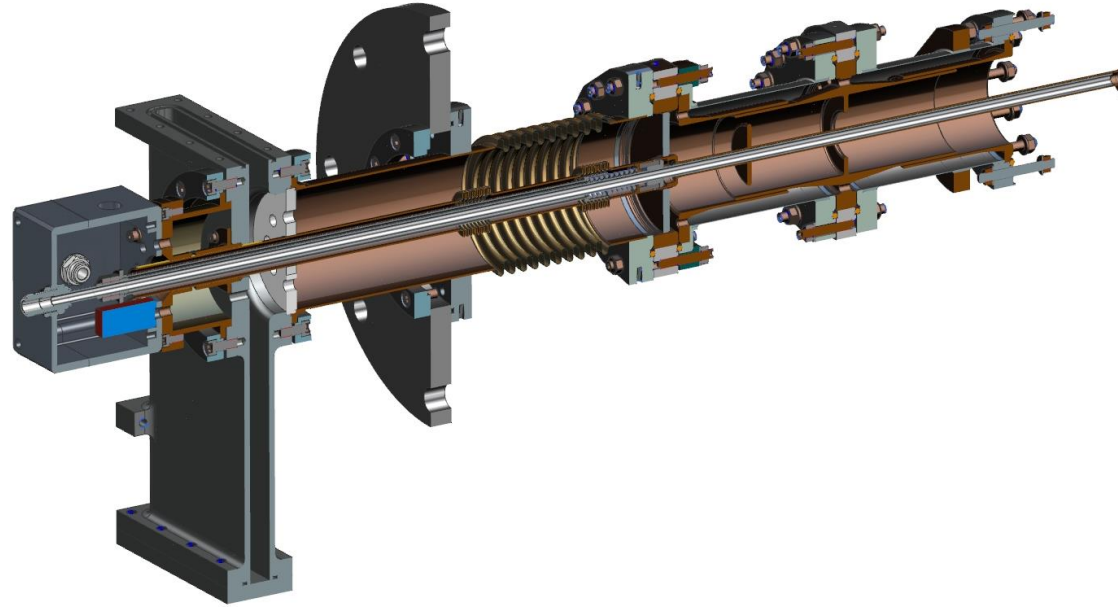
Broken window from CPI.

Vacuum part of antenna was oxidized (after crack). It means the temperature was rather high (~ 200 C ?).

I could not get this temperature in simulation with measured loss tangent (at 100C). Maybe the ceramics was even worse than we think.



650 MHz coupler.



650 MHz coupler were designed considering all experience we got from 325 MHz couplers. Window configuration was changed to make brazing simpler. Couplers we placed for production into CPI from the beginning. Ceramic disks were checked before production. Windows were not coated with TiN. As results, Coupler were produced in time but with small incident: during incoming inspection windows were checked for vacuum tightness in vertical position. All windows were vacuum tight. But in operation horizontal position a small leak appeared at one window. Leak was cured with Vacseal. Window was successfully used for room temperature tests but could not be used for cold tests with SC cavities.

Lesson learned:

- Experience and reliability of vendors is extremely important for coupler fabrication.
- Quality (losses) of each ceramic disks should be checked before using in coupler production.
- We need better understanding how TiN coating works. There is a question: shall we use TiN coting if coupler can work without it?
- Incoming inspection should be performed in operating position.

Thank you.